# CONTROL OF THE ELECTRIC WHEELCHAIR USING EEG CLASSIFICATION

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**Abstract**: Electric wheelchairs are some of the most important devices to assist physically handicapped persons. This paper presents the concept of brain controlled electric wheelchair designed for people who are not able to use other interfaces such as a hand joystick, and in particular for patients suffering from amyotrophic lateral sclerosis (ALS). The objective is to control the direction of an electric wheelchair using noninvasive scalp electroencephalogram (EEG).

**Keywords**: BCI-controlled wheelchair, Brain-computer interface, BCI, Electric wheelchair, Electroencephalography, EEG, Sensorimotor rhythms, SMR, Shared control, Robotics, Robot

## 1 INTRODUCTION

Paralysis following spinal cord injury, brain stem stroke, amyotrophic lateral sclerosis and other disorders can disconnect the brain from the body, eliminating the ability to perform volitional movements. The development of brain-computer interfaces (BCI) is aimed at providing users with the ability to communicate with the external world via a computer through the modulation of thought. Especially in the case when the patient is completely paralyzed, this technology may provide the only possible way for him/her to gain control over basic aspects of his/her daily life by recording their brain activity to extract signals about their motor intentions.

## 2 BRAIN-COMPUTER INTERFACE (BCI)

Brain–computer interfaces (BCI) are systems that aim to restore or enhance a user's ability to interact with the environment via a computer and through the use of only thought. Such a task is achieved through a closed loop of sensing, processing and actuation. Bioelectric signals are sensed and digitized before being passed to a computer system. The computer then interprets fluctuations in the signals through an understanding of the underlying neurophysiology, in order to discern user intent from the changing signal. The final step is the actuation of this intent, in which it is translated into specific commands for a computer or robotic system to execute. The user can then receive feedback in order to adjust his or her thoughts, and then generates new and adapted signals for the BCI system to interpret. General scheme of the BCI is in figure 1.

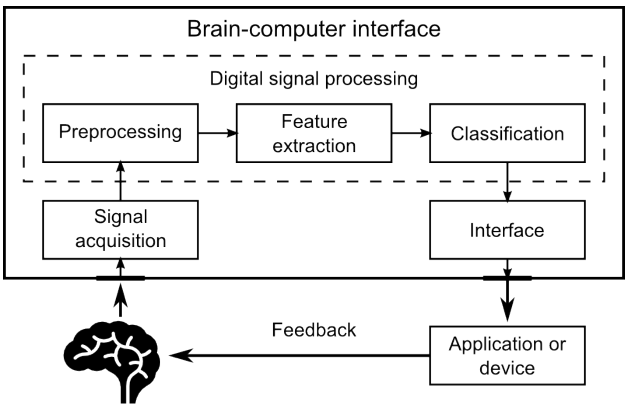


**Figure 1:** Scheme of brain-computer interface

## 3 BCI-CONTROLLED WHEELCHAIR

In comparison with the classical analog joystick the BCI input generally has a limited resolution and higher uncertainty. As with other BCIs, EEG yields a low information transfer rate: either the waiting time between consecutive commands is long, typically several seconds, or uncertainty about the command is high. The difficulty is figuring out how to use such a poor signal to control a wheelchair that requires real-time specification of its position within the 3D space of planar motion. One of the solution is to give the system some autonomy, such that the user must provide the wheelchair with directives only from time to time.

The control signal decoded from the scalp EEG will be sent regularly to shared control system together with signal from proximity sensors on wheelchair. Shared control system using predefined method will determinate speed of each motor which will be sent via WiFi into control unit of wheelchair. Basic architecture of the BCI-controlled wheelchair is in figure 2.

### 3.1 SENSORY MOTOR RHYTHMS CLASSIFICATION

For purposes of controlling electric wheelchair the sensorimotor rhythm (SMR)-based BCIs has been chosen as it provides high speed of control and low incidence of unintentional commands. Methodology of training and control is inspired by team from University of Minnesota which used it to control quadcopter [1].

Subject will be trained in 1D and 2D cursor movement task using motor imagery. EEG data will be acquired and processed using development platform BCI2000 [2]. This software will allow to identify the specific electrodes and frequencies that will be most differentially active during the actuation of a given imagination pair. The spectrogram of the $R^2$ value, a statistical measure of degree of correlation of temporal components of the EEG signal with different imagination state pairings, will be calculated so electrode and frequency bin (3 Hz width) with the highest correlation value to a given imagination state could be used. By evaluation of this spectrogram, the subject specific electrode-frequency configuration will be identified as a control signal for BCI to classify intended movement. [1]

The control signal will be extracted as the spectral amplitude of the chosen electrodes at the selected frequency components. This will be done using BCI2000's online Autoregressive Filter. There will be three different commands proceeded to the shared control system: imagination of squeezing both hands will result in command *forward* or *stop* (depending on whether the wheelchair is already moving), imagination of squeezing left hand will result in command to turn *left*, and imagination of squeezing right hand will result in command to turn *right*. Command for going back is not necessary because wheelchair can turn around its own axis.

### 3.2 SHARED CONTROL

The nature of BCI-classified mental commands, generated by the subject to indicate some desired movement is quite different from those generated by a continuous joystick. First and foremost, there is an important reduction in resolution due to the limited amount of different mental commands that a BCI classifier can reliably discern. As a consequence, a command-to-movement scheme must be adopted which ensures that smooth motion will result from these discrete input signals. The EEG classifier system used in this work is able to distinguish three discrete commands that may express the need for movement into a certain direction. The steering signals that the classifier outputs consist of a probability distribution over these three discrete steering commands: *forward*, *left*, and *right*. [3]

*Forward* or *stop* means that translational speed $v$ should be increased to predefined constant value when chair is not moving or to stop the wheelchair when it is in move. A *left* or *right* signal means that the user intends to rotate the wheelchair in the respective direction, thus increasing or decreasing the rotational velocity $\omega$. Both velocities are superimposed, so that a command to turn when the wheelchair is already moving forward will result in a smoothly curved path.

### 3.3 Obstacle avoiding system

A conventional approach to autonomy is to equip the vehicle with sensors to perform obstacle detection and localization. Approach of using ultrasonic proximity sensors will be used.

Ultrasonic proximity sensors are used in many automated production processes. They send an ultrasonic sound to the target point. This sound is reflected at the target and an echo thrown back to the sensor. The duration of this process is measured and converted into a corresponding distance. Their advantage is their simplicity and they are inexpensive. On the other hand results can be affected by the wind or fluctuating temperatures.

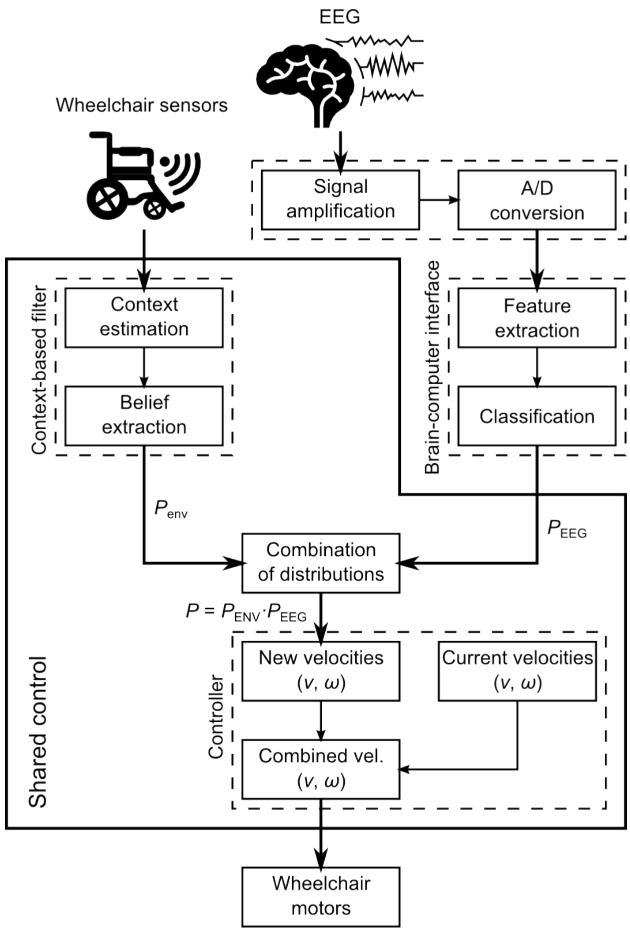


**Figure 2:** Architecture of the BCI-controlled wheelchair

## 4 CONCLUSION

In this paper the method for control of the electric wheelchair using brain-computer interface (BCI) was introduced. This method is based on classification of sensorimotor rhythm (SMR) from scalp EEG. There are four commands implemented (*left*, *right* and *forward/stop*), induced by three motor tasks: imagination of squeezing left hand, right hand or both of them.

## REFERENCES


[1] LaFleur, K., Cassady, K., Doud, A., Shades, K., Rogin, E., and He, B. Quadcopter control in three-dimensional space using a noninvasive motor imagery-based brain-computer interface. *J. Neural Eng. 10*, 4 (Aug 2013).

[2] Schalk, G., McFarland, D. J., Hinterberger, T., Birbaumer, N., and Wolpaw, J. R. Bci2000: a general-purpose brain-computer interface (bci) system. *Biomedical Engineering, IEEE Transactions on 51*, 6 (2004), 1034–1043.

[3] Vanacker, G., Millán, J. d. R., Lew, E., Ferrez, P. W., Moles, F. G., Philips, J., Van Brussel, H., and Nuttin, M. Context-based filtering for assisted brain-actuated wheelchair driving. *Computational Intelligence and Neuroscience 2007* (2007), 1–12.